

[0031] An example electrochemical sensor is mounted to a sensing platform embedded in a contact lens and includes a working electrode and a counter/reference electrode (i.e., a counter electrode that can also serve as a reference electrode). The working electrode can have at least one dimension less than 25 micrometers. In some examples, the working electrode has at least one dimension of about 10 micrometers. The counter/reference electrode can have an area at least five times larger than the working electrode. The electrodes can be situated in a variety of geometries, including co-planar parallel bars, concentric rings, co-axial discs, etc. The working electrode and the combination reference-counter electrode can be formed of platinum, palladium, carbon, silver, gold, other suitable conductive materials, and/or combinations of these, etc. A potentiostat can be connected to the two electrodes to apply a potential to the working electrode with respect to the counter/reference electrode while measuring the current through the working electrode. More particularly, the potential applied to the working electrode can be sufficient to generate oxidation and/or reduction reactions of target analytes, in which case the measured current provides an indication of analyte concentration. The control electronics operate the antenna to wirelessly communicate indications of the current to the external reader.

[0032] Employing a microelectrode, such as a working electrode with a dimension of approximately 10 micrometers, results in currents in typical signal currents of a few nanoamps. At such low currents, and with such electrode dimensions, the diffusion of analyte molecules to the electrode is sufficiently efficient that the amperometric currents readily reach the steady state as a result of the sustainable replenishment of analyte molecules to the working electrode through diffusion.

[0033] Moreover, low currents allow the sensor to be less sensitive to the voltage loss due to resistance of the electrolyte material between the electrodes. That is, sensors with low operating currents generate less voltage loss between their electrodes as a result of their sensor current, even when the material between the electrodes has a relatively high resistance. Thus, where the electrodes are embedded in the polymeric material of the lens, which has a relatively high resistance compared to a typical aqueous solution employed as an electrolyte, the operation of the electrochemical sensor can be enhanced by configuring the working electrode as a microelectrode (e.g., with a dimension less than 25 micrometers, about 10 micrometers, or even less than 10 micrometers).

II. Example Ophthalmic Electronics Platform

[0034] FIG. 1 is a block diagram of a system 100 that includes an eye-mountable device 110 in wireless communication with an external reader 180. The exposed regions of the eye-mountable device 110 are made of a polymeric material 120 formed to be contact-mounted to a corneal surface of an eye. A substrate 130 is embedded in the polymeric material 120 to provide a mounting surface for a power supply 140, a controller 150, bio-interactive electronics 160, and a communication antenna 170. The bio-interactive electronics 160 are operated by the controller 150. The power supply 140 supplies operating voltages to the controller 150 and/or the bio-interactive electronics 160. The antenna 170 is operated by the controller 150 to communicate information to and/or from the eye-mountable device 110. The antenna 170, the controller 150, the power supply 140, and the bio-interactive electronics 160 can all be situated on the embedded substrate 130.

Because the eye-mountable device 110 includes electronics and is configured to be contact-mounted to an eye, it is also referred to herein as an ophthalmic electronics platform.

[0035] To facilitate contact-mounting, the polymeric material 120 can have a concave surface configured to adhere ("mount") to a moistened corneal surface (e.g., by capillary forces with a tear film coating the corneal surface). Additionally or alternatively, the eye-mountable device 110 can be adhered by a vacuum force between the corneal surface and the polymeric material due to the concave curvature. While mounted with the concave surface against the eye, the outward-facing surface of the polymeric material 120 can have a convex curvature that is formed to not interfere with eye-lid motion while the eye-mountable device 110 is mounted to the eye. For example, the polymeric material 120 can be a substantially transparent curved polymeric disk shaped similarly to a contact lens.

[0036] The polymeric material 120 can include one or more biocompatible materials, such as those employed for use in contact lenses or other ophthalmic applications involving direct contact with the corneal surface. The polymeric material 120 can optionally be formed in part from such biocompatible materials or can include an outer coating with such biocompatible materials. The polymeric material 120 can include materials configured to moisturize the corneal surface, such as hydrogels and the like. In some instances, the polymeric material 120 can be a deformable ("non-rigid") material to enhance wearer comfort. In some instances, the polymeric material 120 can be shaped to provide a predetermined, vision-correcting optical power, such as can be provided by a contact lens.

[0037] The substrate 130 includes one or more surfaces suitable for mounting the bio-interactive electronics 160, the controller 150, the power supply 140, and the antenna 170. The substrate 130 can be employed both as a mounting platform for chip-based circuitry (e.g., by flip-chip mounting) and/or as a platform for patterning conductive materials (e.g., gold, platinum, palladium, titanium, copper, aluminum, silver, metals, other conductive materials, combinations of these, etc. to create electrodes, interconnects, antennae, etc. In some embodiments, substantially transparent conductive materials (e.g., indium tin oxide) can be patterned on the substrate 130 to form circuitry, electrodes, etc. For example, the antenna 170 can be formed by depositing a pattern of gold or another conductive material on the substrate 130. Similarly, interconnects 151, 157 between the controller 150 and the bio-interactive electronics 160, and between the controller 150 and the antenna 170, respectively, can be formed by depositing suitable patterns of conductive materials on the substrate 130. A combination of resists, masks, and deposition techniques can be employed to pattern materials on the substrate 130. The substrate 130 can be a relatively rigid material, such as polyethylene terephthalate ("PET") or another material sufficient to structurally support the circuitry and/or electronics within the polymeric material 120. The eye-mountable device 110 can alternatively be arranged with a group of unconnected substrates rather than a single substrate. For example, the controller 150 and a bio-sensor or other bio-interactive electronic component can be mounted to one substrate, while the antenna 170 is mounted to another substrate and the two can be electrically connected via the interconnects 157.

[0038] In some embodiments, the bio-interactive electronics 160 (and the substrate 130) can be positioned away from